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Insects and other Pests Injurious to the Production of Seed in Herbage and Forage Crops

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HERBAGE PUBLICATION SERIES

BULLETIN 20

INSECTS AND OTHER PESTS INJURIOUS TO THE PRODUCTION OF SEED IN HERBAGE AND FORAGE CROPS

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INTRODUCTION.

THE production of seed entails the cultivation of the parent plant from the seed stage upwards to its maturity. Throughout this period there are many insects and allied forms only too willing to take advantage of the plentiful food supply. Not all of these potential enemies habitually cause serious reduction in the amount of seed produced, but should they for some reason become rather more numerous than usual, serious diminution in seed crop may result either directly or indirectly. One has only to think of root feeders, such as wireworms and cockchafer grubs, to realize that sometimes it is almost impossible to obtain a good stand. Similarly cutworms or surface caterpillars, locusts and grasshoppers sometimes ruin a promising plant. Such insects cannot be called seed pests and yet on occasion they are indirectly responsible for poor seed returns.

The agronomist is responsible for the more general aspects of seed production, while the entomologist is called in for advice only when the crop is being or has been ruined by some pest. The consequence is that certain insects are known to be important pests as the result of bitter experience. Following this, certain insect names are used by agronomists and growers alike to denote say a beetle or a maggot attack. These names come readily to their lips and often no care is taken to ascertain which particular beetle or maggot is really the one responsible. The grower likes to be able to refer to an insect by its Latin or so-called scientific name—the agronomist has not fully appreciated the immense number of different kinds of insects and the diversity of their habits which go to make or mar the entomologists' recommendations for their control. He is in other words rather too ready to follow the principle of giving a dog a bad name.

The entomologist is full of his knowledge of insect names and altogether too "scientific" for the growers. When asked for the insect pests of, for instance, lucerne, he is liable to mention thirty or forty names of insects which have in fact been recorded from lucerne. By so doing he only confirms the idea of narrowness and over-specialization—that he does not consider insects in their proper perspective or appreciate the innate difficulties of the grower who is too optimistic and whose life is too short and full of everyday troubles to be bothered with all the insects feeding on a particular crop. What the grower wants is a clear exposition of the insects which can reasonably be expected to occur as pests in his particular area, not merely those that have already proved themselves pests; he probably is familiar with the latter.

There is a real need for further investigation into the insect pests of herbage and forage crops—the geographical range of such pests, the risk of their being transported from one country to another and their chance of survival if so transported, the exact amount of damage to seed production, whether some insects act as natural pruners of excessive leafy growth, and so on. The desirability of closer co-operation and a better understanding of mutual problems between grower, agronomist and entomologist is too obvious to need further elaboration.

It is proposed in this paper to deal briefly with those insects which have come to the notice of seed producers in the general care of the plants; that is, those causing indirect injury to seed production; to describe in more detail those insects which directly cause the loss of seed; and finally to mention certain other insects which may from their habits become pests. In each case care will be taken to state, as far as is at present possible, in which countries the pests occur or are likely to do so, the nature of the damage, characters by which the pest may be recognized and control measures. The paper is divided into two sections, that dealing with grasses and that dealing with legumes.

GRASSES. 1. GENERAL AND INDIRECT PESTS.

Wireworms (Drahtwürmern, taupin).

Wireworm is the term applied to the larvae of click beetles belonging to the family Elateridae. There are many different kinds classified in several genera, such as *Agriotes* and *Athous* in Europe and Russia; *Phletes*, *Melanotus* and *Limonius* in the North American continent; and *Chrosis*, *Corymbites* and *Monocrepidius* in Australia and New Zealand.

They are world-wide in distribution and are considered major pests to the roots of grain, grass, root crops and many other plants in many countries. In the U.S.S.R. they have been reported as pests of several grasses grown for seed, e.g. *Agriotes sputator* attacking *Agrostis alba*, *Alopecurus pratensis*, *Bromus inermis*, *Phleum pratense*, *Dactylis glomerata* and *Poa pratensis*. In Germany wireworms have been recorded as being harmful to young sowings of *Festuca pratensis*.

The symptoms of attack are young plants dying out in the autumn or spring in irregular patches in the fields. The larvae are about an inch long, slender, shining, smooth, tough and yellow or yellowish-brown and may be found among the roots. The adult beetles are usually dull in colour, tapering in shape and possess the characteristic habit of 'clicking' in order to right themselves when placed on their backs.

The life cycle is long and takes several years to complete. In the case of *Agriotes*, the larvae hatch from the egg in July after about four weeks. The larvae moult about twice a year and eight times before becoming full-grown. Up to the fourth stage they are chiefly humus feeders, but later become root feeders. Pupation takes place during the summer and autumn and the beetles emerge in the late summer and pass the winter hibernating in the soil. Egg-laying occurs in the May and June of the fifth year after the egg stage of the ovipositing beetles.

The control of wireworms is exceedingly difficult and no really certain method has been discovered. Among direct methods are the use of soil insecticides, baits and trap crops. Promising soil insecticides are chlorpicrin, various cyanides, especially sodium, and ortho and para dichlorobenzene (naphthalene has also been found useful under certain soil conditions); heaps of clover or lucerne poisoned with arsenic or Paris green are useful baits; and the method of sowing rows of wheat or oats as an attractant crop with calcium cyanide drilled in about fourteen days later, with subsequent rolling of the soil has proved efficient. Among indirect or cultural methods bastard fallowing with deep furrows is recommended. The sowing of extra seed, firm packing of seed beds and the avoidance of using freshly broken up old grassland have also been suggested. Russian agronomists have recommended poisoned baits such as bran with white arsenic or Paris green against wireworm attacks on grasses being grown for seed. These baits should be covered with a board.

Chafer Grubs (Maikäferlarven, Blatthornkäferlarven, ver blanc, white grubs or grub worms).

Chafer grubs are the larvae of chafer beetles (or June bugs) belonging to the family Scarabaeidae. There are several different kinds belonging to such genera as *Melolontha*, *Rhizotrogus* and *Phyllopertha* in Europe and Russia, *Phyllophaga* in the North American continent and *Odontria* in New Zealand.

They are widely distributed throughout the world and are well known as general cereal and grass root pests, as well as being injurious to the roots of other plants. In the United States of America grub worms have been recorded as injurious to

Agrostis alba grown for seed, while in Rumania *Melolontha* grubs have been reported as being harmful to *Lolium perenne*.

The damage is done to the roots of grasses by the larvae, the adult beetle feeding on the leaves of trees, especially oak. The larvae are thick bodied, large, white, swollen in appearance with brown heads and jaws, characteristically strongly curved in shape and reaching an inch across the curved body. The beetles are large, convex, with the antennae or feelers bearing leaf-like appendages. In certain cases they have brown wing-cases and brown and white abdomens.

Most of the life-cycle is spent underground and usually takes about three years to complete. The eggs are laid in April-June in the soil; the larvae are hatched by July. Increasing damage is done in each successive year of the larvae's life. Pupation takes place in the August of the third year and the adults are developed by the autumn, but remain in the pupal cells below ground until the spring (4th year).

Control is difficult. General cultural methods, such as never following grass by cereals but by some crop like clover, and early autumn ploughing have been recommended. Likewise, allowing poultry or pigs to run over infested land is beneficial. Heavy steam rolling has also had good effect on occasion. On small areas the use of sodium cyanide as a soil insecticide is suggested. All the above measures aim at killing the larvae. Considerable good can be done in reducing the numbers by collecting the adult beetles and destroying them. In the United States of America general control measures for grass insects have been recommended, while in Rumania the beetles are collected by hand.

Surface Caterpillars (Erdruppen, vers gris, cutworms and army worms).

Cutworms are the caterpillars of moths belonging to the family Noctuidae and are world-wide in distribution. There are numerous different kinds, well-known as pests of agricultural crops in most countries, especially America and Russia.

Several kinds have been reported by seed agronomists. For example, in South Africa *Laphygma exempta* has damaged *Eragrostis*; in Sweden *Hadena secalis* sometimes causes the withering of the heads of *Phleum pratense* by nibbling the stems; in Canada *Agropyron cristatum* and *Bromus inermis* seedlings have suffered in large outbreaks of these caterpillars; in the U.S.A. the army worm (*Cirphis unipuncta*) has been recorded as attacking *Agrostis alba* and *Phleum pratense*; and *Euxoa segetum* has been reported in Hungary as a pest of *Dactylis glomerata*, *Festuca pratensis* and *Lolium perenne* and in England on *Lolium*.

Surface caterpillars cause great damage to the leaves and stems, tubers, underground stems and roots of many plants and also decapitate seedlings. They often escape notice because of their nocturnal feeding habits. They are usually greenish and brownish in colour and are typical caterpillars. In the daytime they lie up in the soil around the plants they are attacking. The moths are of subdued brownish coloration.

Most of these moths are on the wing in July and August and lay their eggs on the leaves and stems of numerous low-growing plants. The young caterpillars hatch in about fourteen days and feed on as far into the autumn as the temperature allows. In the spring the greatest damage is done, as the caterpillars nearing full growth are voracious feeders. They are full-grown in the late spring and early summer and pupate in the soil. The moths emerge in the late summer. They complete their life cycle in one year.

These pests seem to suffer from excessive dampness and for this reason a wet summer is often followed by a diminution in their numbers. Light friable soils are most heavily infested. The usual method of control is the use of poisoned baits:

About 20 lb. of bran mixed with 1 lb. of Paris green and moistened with treacle or molasses is sufficient for an acre. Running poultry over infested land will also be of distinct advantage under certain circumstances.

Grasshoppers and Locusts (Heuschrecken, sauterelles et criquets, grasshoppers not locusts in the U.S.A.).

Grasshoppers and locusts are world-wide in distribution and belong to the family Acridiidae. They include the common grasshoppers of the countryside as well as the highly specialized migratory forms. In the United States of America unfortunately, the term 'locusts' is frequently meant to refer to an entirely different group of insects, the Cicadidae.

Grasshoppers have been reported in times of severe outbreaks as injurious in Canada, especially in the prairie provinces, to *Agropyron cristatum*, *A. pauciflorum* and *Bromus inermis*. Usually the young seedlings of the latter grass are attacked, but sometimes the panicles also suffer, thus greatly diminishing seed returns. In the United States of America, grasshoppers have likewise been reported as injurious to *Agropyron cristatum* and *Agrostis* grown for seed. In the Union of South Africa, the well-known Brown locust (*Locustana pardalina*) has been noted as damaging *Eragrostis* grown for seed.

These insects merely eat up the plants. They are too well known in general appearance to need any description. The eggs are laid in the soil and in the spring the young grasshoppers hatch. Some, however, hatch in the late summer and pass the winter in the young stages. These latter kinds are far less injurious than those which hatch in the spring. The height of feeding activity takes place when the temperature reaches about 78°F. Growth is completed by about August and the eggs are laid in the autumn.

Cultural control measures, such as deep ploughing in the autumn followed by harrowing, are effective in destroying the eggs when land is known to be infested. Shallow cultivation also in the autumn to expose the eggs to the weather is beneficial.

Poisoned baits are the most effective means of destroying grasshoppers. A formula in use in the U.S.A. is:—

25 lb. of bran or half bran and half sawdust,
1 lb. sodium arsenite, Paris green or white arsenic,
2 quarts of molasses,

with sufficient water to make a stiff mash, usually about 2 to 3 gallons.

Another bait, the Criddle mixture, used especially in Canada, is:—

100 lb. horse droppings,
5 lb. white arsenic or Paris green,
2 lb. salt,

with sufficient water to moisten.

The success of these baits depend largely on the weather conditions—fair, with a temperature of about 75°F. in the shade, certainly not less than 68°F.; under these conditions the appetites of the grasshoppers are keenest.

Grasshoppers may also be caught in hopperdozers—narrow wooden or metal troughs partially filled with a mixture of kerosene and water and a shield of boards at the back, the whole being mounted on wheels so that they can be drawn across the fields. The hoppers jump up, hit the shield and fall into the trough, where they are killed.

Miscellaneous general Pests.

In addition to these outstanding general and indirect seed pests, various other insects and animals have been reported in different parts of the world as being harmful to seed production in grasses. Among these should be mentioned the following : leafhoppers and scale insects on *Agrostis alba*, chinch bugs on *Andropogon sorghum* var. *Sudanensis* and termites to *Chloris gayana* in the United States of America ; stemborers in *Andropogon sorghum* and *Zea mays* in India ; mice and moles to *Dactylis glomerata* and *Festuca pratensis* in Hungary ; and lastly, slugs to young plants of *Festuca pratensis* in Germany. This last mentioned pest is likely to occur anywhere in the world.

GRASSES. 2. PARTICULAR AND DIRECT PESTS.

No real hard and fast lines of distinction can be drawn between 'general and indirect' pests and 'particular and direct' ones. In this section for convenience are included in this latter category such stem pests of grasses as the wheat stem sawfly, the timothy joint worm, the frit fly group of stem flies, particular cutworms such as *Apamea secalis* and *Miana strigilis*, and various stem infesting mites such as *Pediculopsis graminum*. In addition a note dealing with the disease of grasses and cereals known as 'white-ear' is given. Then three leaf-feeding insects, a small moth, a Jassid and a Capsid receive attention. Finally, grass head pests such as thrips, the timothy flies, the cocksfoot moth and the foxtail gall midges are discussed.

The Wheat Stem Sawflies.

There are two closely allied species, *Cephus pygmaeus* and *C. cinctus*; the former is distributed throughout Europe, Russia, N. Africa and has been recorded from N. America, whereas *C. cinctus* is restricted to the United States of America and Canada.

The damage caused by both these insects is notorious on cereals such as wheat, barley and rye. There are also numerous records of attacks on timothy, quack-grass, bromes and other meadow grasses. In the prairie provinces of Canada, *C. cinctus* has been reported attacking *Agropyron pauciflorum* being grown for seed; in Germany *C. pygmaeus* is recorded from meadow grasses.

Injury is recognized in two ways—the ears become white and stand unusually erect, and the straw falls. The adult sawfly is wasp-like in appearance, black with yellow bands, similar in size but more slender. The larva is a dull yellowish-white grub.

The life cycle is similar in both species. The winter is passed as fully-grown larvae in the base of the stems. In the spring pupation takes place and the adults emerge in June. There is only one generation a year. The eggs are placed high up on the stems and the larvae hatch in about 7 to 10 days. They feed inside, boring downwards to the lower parts which they reach by the autumn.

As control, the stubble should be burnt and rotation should be practised. Biological control, i.e. the transportation of natural parasites of *C. pygmaeus* from Europe to Canada to attack *C. cinctus*, has been attempted.

Timothy Joint Worm.

Another insect causing similar damage is the timothy joint worm (*Harmolita* (*Isosoma*) sp.). This pest seems to be restricted to N. America. There are, however, other *Harmolita* species throughout northern Europe and Russia.

In the U.S.A. it often causes some of the heads of *Phleum pratense* to dry prematurely. The adult insect is almost entirely black and quite small, about 0.10 to 0.125 of an inch in length.

The eggs are laid in the stems, several at one place, and the larvae feed inside the stalks, causing hard gall-like swellings to develop. These swellings contain the yellowish larvae and can be found at various heights depending on the growth of the plant at the time of egg-laying. The winter is passed in both the larval and the pupal stages. The stalks of infested plants become brittle and break off.

Burning or ploughing in the stubble, in order to prevent the emergence of the adults in the spring, as well as rotation of crops, are recommended as control against this pest.

Stem Flies.

There are many flies whose grubs live inside the stems of grasses and cereals causing considerable damage. They belong to various genera such as *Oscinella*, *Meromyza*, *Elachiptera*, *Opomyza*, and *Chlorops*. Among the better known is the Frit Fly (*Oscinella frit*).

These flies are world-wide in distribution and much research work has been carried out on them, especially in France and Russia. They are exceedingly difficult to separate into the different species. In Germany frit flies have been reported on *Festuca pratensis* being grown for seed.

There are three kinds of damage: the autumn and winter type, the spring, and the summer. The first is a stunted appearance of the plant attacked, the next is a yellowing and dying off of the central shoot and the last is a whitening of the heads and withering of the upper portion of the stems. The flies are small, about 0.1 to 0.2 inches in length; the frit fly is black in colour (others are yellowish-white with brown or black stripes along the thorax and body). The larvae are whitish maggots.

Each kind of fly has a slightly different life cycle. Some have only two generations a year, others three or more, but in the main they are similar. That of the frit fly is considered below as a more or less typical example. In this case there are three generations a year. The winter is spent as larvae in the stunted plants, pupation occurs in the spring and the first flight of the flies takes place from April to the end of May. These flies lay eggs on the lower leaf blades and the larvae work their way to the central shoot on which they live. This spring generation is completed in about forty days. The flies of the second or summer generation are on the wing from the end of May until the middle of August, with maximum numbers in the middle of July. The eggs are laid in the ears or grass heads and the larvae feed on the developing seed. The third or autumn flight occurs from the end of July until September and the eggs are laid on meadow grasses, volunteer and autumn-sown cereals.

The frit fly is a serious pest of oats, barley, wheat, rye and maize. In Great Britain it occurs chiefly on oats, in Central Europe on barley, in N. America on wheat. It has also been reported from such grasses as *Agropyron repens*, *Lolium*, *Festuca*, and *Poa*.

No practical method of controlling this group of flies has been discovered. Cultural methods such as alteration in the date of seeding have been recommended and have been partially successful. The older the stand of grass the more liable is it to heavy infestations. For cereals the breeding of resistant strains is receiving attention.

Apamea (Hadena, Trachea) secalis.

There are several caterpillars which live in the stems of grasses. There is space here to mention only two, which may be taken as typical.

Apamea secalis is a Noctuid moth distributed over a large range, spreading across northern Europe and Asia as far as Japan. It is well-known as a pest of cereals, especially rye, in such countries as Germany, Denmark, Norway, Russia, and Japan. In Ireland it damages *Alopecurus pratensis* grown for seed.

The damage is caused by the caterpillars which live inside the stems, with the result that the central shoots become discoloured and die, damage similar in appearance to that caused by the spring generation of the frit fly. Another type of injury has recently been reported from Northern Ireland and England. In this case the grass heads themselves suffer and after attack present an appearance very like that produced on timothy heads by the timothy flies (q.v.). The caterpillars in such cases destroy the heads before the latter emerge from the sheaths. The moths are brownish in colour and the caterpillars are green with reddish-brown lines down the back.

There is but one generation a year ; the caterpillars can be found from September until the following April and May. Pupation takes place in the soil and the moth is on the wing in July, August and September.

No control has so far been suggested.

Miana (*Hadena*) *strigilis*.

The caterpillar of this Noctuid moth does damage similar to that caused to the central shoots of many grasses by *Apamea secalis*. Its life history is also similar. It is restricted to *Dactylis glomerata*. It occurs throughout Europe and in Russia. Damage to *D. glomerata* grown for seed has been reported from Denmark.

Stem Mites.

There are at least three species of mites which damage grasses—*Pediculopsis graminum*, *Tarsonemus culmicola* and *T. spirifex*—which should be mentioned.

Pediculopsis graminum is well known as a pest in Finland, Norway, Sweden, Germany, Holland, Hungary, Russia and also occurs in N. America. *Tarsonemus culmicola* seems to be restricted to Finland. These mites live in numbers on the stems of several grasses and cereals. They suck the plant juices and so cause a serious shortage, resulting in white ears and heads. Complete sterility and absence of seeds follow. They live under the sheaths of the central stem and so often escape notice. However, they have been associated with this whitening of the ears on *Festuca pratensis* in Germany and the Scandinavian countries, on *F. rubra* var. *genuina* in Czechoslovakia, on *Poa pratensis*, *trivialis* and *fertilis* in Hungary and on *Poa pratensis* in Sweden.

Tarsonemus spirifex causes a spiral malformation of the central stem, and, although it does a little damage by reducing the flow of sap to the developing ear, it is usually of more interest than importance.

All these mites have four pairs of legs and are minute, being scarcely visible to the naked eye. Their life histories are only partly understood. Their control is a matter of great difficulty. The most effective method seems to be to plough up the field and substitute the cultivation of clovers for several years. Here again the older the stand the more favourable it is for the pest. Strict cultivation among the grass plants from the beginning will, however, reduce the chances of the whole field being affected, as occurs when fields are uncultivated.

'White-ear' (Weissährigkeit).

The term 'white-ear' is of frequent occurrence in the literature dealing with pests and diseases of grasses and cereals. It is used to denote an abnormal whiteness of the heads or ears accompanied by sterility and lack of seed formation. Some English workers have claimed that such damage on cereals is the work of thrips, e.g. *Limothrips cerealium*, *L. denticornis* and *Aptinothrips rufus*; other workers in Germany have denied this; another in Poland has stated that the injury is due to mechanical causes, chiefly winds. Certain Scandinavian workers are convinced that the mites *Pediculopsis graminum* and *Tarsonemus culmicola* are the cause of 'white-ear' among grasses. Other investigators have stated that 'white-ear' is caused by many insects: by stem flies such as *Oscinella*, *Meromyza*, *Elachiptera*, *Chlorops* and certain Cecidomyids; by caterpillars such as *Apamea secalis*, *Anerastia lotella*, *Ochsenheimeria taurella*; by the stem sawfly, *Cephus pygmaeus*; by thrips, *Chirothrips hamatus* and *Haplothrips aculeatus* in addition to those mentioned above; and by the above-mentioned mites.

This wider view of 'white-ear' disease is the more correct. It is a term used to describe the symptoms of a disease and should not be used to denote or imply the cause. Many insects cause such injury to the plant that white ears or heads result. It is also possible that fungous diseases, mechanical and physiological factors and soil deficiencies may have the same result. 'White-ear' is a term to be avoided.

Tortrix paleana (Timotheewickler).

This is a small Tortricid moth which is distributed throughout northern and central Europe. It is a well known pest of timothy, foxtail and other broad-leaved grasses in Sweden and Finland. It also attacks red clover in Finland and Norway and oats in Denmark.

The caterpillars do the damage, feeding inside webs on the plants. The moths are whitish-grey. The caterpillars are blackish with white spots and black heads, being about half an inch long when full-grown.

The egg stage lasts for about 6 days in July, the caterpillar stage from July until the following June (11 months) and the pupal stage 10 to 14 days at the end of June or in July. There is usually one generation a year, but in abnormally favourable years there are two in Sweden. On emergence the young caterpillars spin a web knitting the foliage together into tubes and here they overwinter, feeding in the late summer and following spring. They also pupate in these tubes.

There are several natural controls: a fungus, a disease (probably bacterial) and three Hymenopterous parasites, *Glypta bicornis*, *Macrocentrus nitidus* and *Habrocyptus brachyurus* (reported from Finland only so far). The mite *Anystis baccharum* has been seen feeding on the newly-hatched caterpillars. In spite of these natural agencies, there are outbreaks of this pest in some years. In cases of slight infestation burning at places where haystacks stood is recommended. In severe outbreaks premature harvesting is carried out and in such cases care must be taken to cart the hay immediately from the fields for use as green fodder or for drying indoors.

Timothy Crown Leafhopper.

This insect (*Acocephalus albifrons*) sometimes causes the stunting of timothy in the United States of America. The winter is passed in the egg stage. They are laid in the late summer and autumn, probably hatch in May or June and reach the adult stage in July. The young nymphs attack the base of the stems and the crowns. Later the leaves and stems are damaged. The family of leafhoppers (Jassidae or Cicadellidae) to which this insect belongs are sucking insects, as are aphids or green flies. They occur all over the world on grasses as well as on other plants, but up to the present in Europe they have received scant attention. Rotation and burning over the infested land are recommended in the United States.

Miris dolobratius.

This insect is another sucking type and belongs to the family Capsidae. It occurs in northern Europe, Russia and N. America. In some years this bug appears in such numbers in Sweden as to cause the leaves and stalks of grasses and cereals to become white and the ears in such cases fail to develop normally.

The insects are full grown at the end of June and the eggs are inserted into the stalks at a low level. The eggs are stated to hibernate and hatch at the beginning of May. Development of the bugs is completed in about six weeks in Sweden.

Ploughing the fields to destroy the eggs has been suggested as a control.

Thrips.

Thrips are small sucking insects of world-wide distribution and attack many grasses and cereals. The damage is a whitening of the grass heads sometimes accompanied by complete sterility. There are several different kinds on grasses, e.g. *Aptinothrips rufus*, *Limothrips cerealium*, *L. denticornis*, *Heliothrips aculeatus*, *Chirothrips hamatus* and *Bolacothrips jordani*. Serious damage has, for instance, been caused to *Alopecurus pratensis* grown for seed in Finland recently by the two last mentioned species.

Their life histories are similar. In the case of *Limothrips cerealium* the winter is passed in the adult stage in the soil, stubble and clumps of grasses. Thrips are about one-twelfth of an inch long and black. The immature stages are yellow in contrast. Winged females come from hibernation in April and May, the males are short lived. Eggs are laid on the grasses and the whole life history from egg to adult takes about 40 days. In addition to feeding on the leaves, the thrips also attack the heads and it is this attack that causes serious damage.

Control measures are limited to attempting to destroy their winter quarters by harrowing and burning the stubble in the early spring.

Timothy Flies.

There are two species commonly known as *Amaurosoma flavipes* and *A. armillatum*, but some workers recently consider the former should be known as *Trichopalpus punctipes*. They occur in Northern Europe and Russia and have also been reported from Austria. They are familiar pests of *Phleum pratense*, *A. armillatum* in some years doing great damage in the west of Scotland and both species in Scandinavian countries.

The damage consists of a partial stripping of the heads before they emerge from the sheath. The flower buds are cut off. The flies are dark grey and of moderate size, about 0.25 inches long.

Eggs are laid in May at the base of the leaf sheaths and the maggot bores into the stem until it reaches the developing ear on which it feeds. It moves up inside the stem as the ear grows until, when the head is ready to burst from the sheath, it is full grown and falls to the ground where it pupates. The pupae remain in the soil until the following spring. There is only one brood a year. The larval stage takes about 15 days to complete.

Among their natural controlling agencies, the following parasitic Hymenoptera have been recorded:—*Seladerma lactum* and *Dacnusa semirugosa* from *A. armillatum*; *Microbracon exhilarator* and a species of *Lamprotatus* from material including both species of flies.

Control is difficult, and unnecessary in some years as there appear to be waves of abundance and scarcity, perhaps due to the degree of prevalence of the parasites. It does not appear feasible to obtain strains of the grass which flower outside the period of possible attack. Investigations to find an adequate soil insecticide to kill the pupae have not yet been successful. However, an emulsion of crude naphthalene in ground-nut oil has given promising results when used as a deterrent to the flies laying their eggs.

Cocksfoot Moth.

The cocksfoot moth (*Glyphipteryx fischeriella*) is a small, brightly coloured moth, about 0.2 inches long with bright yellow markings on the otherwise brownish wings. It has done considerable damage to the seed production of *Dactylis glomerata* at Aberystwyth in Wales and occurs in other parts of England.

The small caterpillars, which are whitish with dark heads, feed on the seeds.

The moths fly about actively on sunny days around the cocksfoot heads at the end of May. The eggs are laid at the base of the seeds about the middle of June and the larvae hatch about two weeks later. The newly-hatched larva burrows into a seed, passing on to another as soon as it has eaten the previous one. The larvae become full-grown in about a month and spin their cocoons either between the seeds or away from the plants among the surrounding herbage; some merely block themselves in a hollowed-out seed. Here they hibernate. Pupation occurs in the spring and lasts nearly four weeks. There is a distinct danger of this insect being transported from one country to another in dirty seed.

The degree of infestation varies in different strains of cocksfoot; American, French and Danish strains suffered less than Swedish and Welsh types. The numbers of moths fluctuate considerably from year to year.

Clean cultivation might diminish the chances of successful hibernation. The larvae in the seed can be destroyed by subjecting them to a temperature of 140°F (60°C.) for 24 hours in an airtight chamber. This treatment does not affect germination of the seed.

Foxtail Gall Midges.

There are three species of gall midges (Cecidomyiidae) which prevent seed formation in *Alopecurus pratensis*. Two are well known, *Dasyneura alopecuri* and *Stenodiplosis geniculati*. The third, *Contarinia merceri*, was described only about seven years ago.

D. alopecuri occurs in Great Britain and the Scandinavian countries where it has been recognized as a serious pest for many years. It has been transported in seed to New Zealand where it virtually stopped the production of *Alopecurus* seed. *S. geniculati* has the same distribution, although there is some doubt as to whether it really occurs in New Zealand. Both these species have recently been reported from Canada, probably also introduced. The third species is so far only known from Great Britain and Finland.

The adult midges are small frail gnat-like flies with long legs. The larvae which do the damage are golden yellow in the case of *C. merceri*, orange to brick-red in *D. alopecuri* and buff to salmon pink in *S. geniculati*.

The larvae of the two last-mentioned species live one per seed on the formed seed, each larva being responsible for the loss of one seed. *C. merceri* larvae live several together in one floret and prevent the seed from forming. Often empty florets are the only indication of their previous presence. Very large numbers of larvae can be found in the heads of the grass, 20,000 of *C. merceri* alone being found sometimes in 100 grass-heads. *C. merceri* larvae remain in the grass heads only a few weeks before descending to the soil where they pass the winter. There is only one main generation a year in this species and also in *D. alopecuri*; in *S. geniculati* there are two. All these three species are on the wing in May and lay their eggs in the grass heads. The larvae of *D. alopecuri* and *S. geniculati* remain in the seed cases over winter and can thus be taken from one country to another in dirty seed. *C. merceri* can rarely be taken across the seas; it has once been found among seed from Finland that had been sent to England. This, however, is not usual.

Control in the field may be effected by preventing the grass from flowering, either by cutting or by grazing, until after the midges have been on the wing. The danger of this is that the seed does not always set properly on late-flowering grass. Larvae of the two species which remain in the seed cases can be killed by heating the seed for 35 minutes to a temperature of 140°F. or by treatment with carbon bisulphide (1 gr. CS₂ to a litre of air) for nine hours. Keeping the seed is not so safe a precaution, as the larvae have been proved to withstand exceedingly long periods of drought.

GRASSES. 3. INSECTS WHICH CAUSE DIRECT INJURY TO SEED DEVELOPMENT AND MAY BECOME PESTS.

The most important insects in this category are various kinds of gall midges (Cecidomyiidae). Recent investigations in England and Germany have shown rather an amazing state of affairs. Cocksfoot seed is attacked by two species in England (*Contarinia dactylidis* and *Dasyneura dactylidis*). Ryegrass is attacked in England by *Contarinia lolii*. *Festuca*, *Poa*, *Eragrostis*, *Agrostis*, *Phleum*, *Briza*, *Agropyron*, *Arrhenatherum*, *Andropogon* and *Pennisetum* all have their own specific gall midge or midges which prevent seed formation. In Germany the seed returns of *Poa* have been considerably reduced by the presence of gall midge larvae. Some of these gall midges can be transported readily from one country to another, and occasionally they occur in enormous numbers. This group is one which demands great respect and precaution to avert serious losses, especially in new seed-producing areas.

LEGUMES. 1. GENERAL AND INDIRECT PESTS.

Wireworms.

While wireworms damage the roots of legumes, the latter are not so susceptible to attack as grasses and cereals. *Agriotes sputator* has been recorded as injuring lucerne, hybrid lucerne and red clover grown for seed in Russia.

Chafers and White Grubs.

These insects afford another instance of general root feeders. In Rumania *Melolontha* grubs have been reported as damaging red clover grown for seed. In Hungary *Melolontha melolontha* (= *vulgaris*) has been recorded as injuring lucerne grown for seed. Deep autumn ploughing and the collection of the grubs and adult beetles are recommended.

Surface Caterpillars.

Various surface caterpillars or cutworms have been reported damaging legumes grown for seed. For example, in Canada whole stands of sweet clover have been destroyed in years of severe cutworm outbreaks. Damage can be avoided by delaying seeding until the danger of severe consequences is past. The red-backed cutworm, *Euxoa ochrogaster*, can be controlled by suitable cultivation and the use of poison baits. Another species, the pale western cutworm, *Porosagrotis orthogonia*, can be controlled only by cultivation methods; baits are ineffective on account of the underground habits of this caterpillar. This latter species normally feeds underground except when the soil is wet. When forced above ground by heavy rains or irrigation, they are attacked by their natural parasites. Thus, when the season is dry enough for them to remain below in May and June, the chief period of the caterpillars' activity, the parasites cannot reach them and an epidemic outbreak of the cutworms may occur the following year. Using this knowledge, it is possible to predict outbreaks by counting the number of wet days in May and June. If there are more than 15 days on which it is too wet to work the soil, little trouble may be expected the following year. Less than 10 such days, however, indicates that the danger of a serious outbreak is considerable.

In the North-West Frontier province of India two kinds of cutworms have attracted attention. *Laphygma exigua* and *Heliothis obsoleta* have been reported damaging *Trifolium alexandrinum* and *T. resupinatum* being grown for seed. In that country handpicking and destruction of eggs and caterpillars have been suggested as a control. In the Anglo-Egyptian Sudan also, these two insects have been recorded as attacking lucerne grown for seed. Both of these species are on record from almost every country in the world and are well-known general pests.

In the United States of America the velvet bean caterpillar, *Anticarsia gemmatilis*, is well-known as a leaf-eating pest of velvet beans, *Mucuna (Stizolobium) deeringiana*. This caterpillar is also known to attack such legumes as cowpeas, lima beans, soybeans, peanuts and lucerne. It also occurs in Barbados, Cuba, and Peru. Insecticidal control is recommended only where necessary to allow maturity of a desired seed crop. Sodium or barium fluosilicate at the rate of 15 to 16 lb. per acre is efficient.

In this group of caterpillars there are several whose adult moths migrate regularly; among such can be cited *Laphygma exigua*, *Heliothis obsoleta*, *Cirphis unipuncta* and *Anticarsia gemmatilis*.

Grasshoppers.

Grasshoppers have been noted as injurious to alfalfa grown for seed in Arizona, U.S.A. The usual poison bait treatment was recommended.

Miscellaneous Pests.

In addition to the pests specifically dealt with in this paper there are several which growers have come across from time to time. For example, in India there is a leafminer which damages cowpeas (*Vigna unguiculata* = *catjang*); in Ceylon mealy bugs have been reported as injurious to *Pueraria phaseoloides* (= *javanica*) grown for seed. Lucerne growers in Hungary have been troubled by mice, others in the Anglo-Egyptian Sudan by a species of thrips, *Hercothrips* (*Heliothrips*) *sudanensis*. White clover growers in Hungary have recorded mice as being harmful; those growing red clover in England and many other places are troubled by clover sickness, caused by an eelworm, *Anguillulina dipsaci* (*devastatrix*), which also attacks white clover; in Wales pigeons are sometimes a nuisance to growers of red clover; and in Western Australia the red-legged mite, *Halotydaeus destructor*, is a pest of subterranean and drooping-flowered clovers.

LEGUMES. 2. PARTICULAR AND INDIRECT PESTS.

In the first part of this bulletin, dealing with pests of grasses, certain pests were included for convenience in a section on 'particular and direct pests.' In the present part on the pests of legumes, it is more convenient to have an additional section dealing with 'particular and indirect pests,' but there are still no hard and fast lines of distinction.

The first insect to be dealt with in the present section is *Sminthurus viridis*, the lucerne flea. Then certain aphids or green-fly, some plant bugs and leaf-hoppers are considered. After describing some Pierid butterflies whose caterpillars damage lucerne, one comes next to a consideration of several beetles. First is a Scolytid whose grubs tunnel the roots of clover, then the weevils, some of which destroy the nodules on the roots, another devours the roots, and others feed on the leaves. Then, finally in this section two leaf-eating ladybird beetles and a Chrysomelid leaf-eating beetle receive attention.

***Sminthurus viridis* (Lucerne Flea).**

This is a curiously shaped insect, about 0.10 inches in length, but the body is subglobular. It belongs to the order of insects known as Collembola or spring-tails, so named because of a forked and ventral springing organ, by means of which they leap into the air. They are wingless and have no metamorphosis. *S. viridis* is known as a pest of lucerne and clovers in Europe, Russia and especially in Australia. It also attacks grasses, root crops and cereals, particularly in the seedling stage.

In Western Australia it has been noted as a pest of subterranean clover and drooping-flowered clover (*T. cernuum*) grown for seed.

The damage is typical. The insects make holes in the leaves similar to those made by flea-beetles and they feed on the mesophyll tissue between the two epidermal layers of the leaves which assume a characteristic transparency. *S. viridis* is pale yellow-green in colour.

The eggs are laid in packets, containing on the average 60 eggs, in the soil in the autumn. They hatch the following spring. In three weeks development is completed by passing through a number of moults. There are five or six generations a year. Temperature and humidity are exceedingly important factors controlling the increase or decrease in numbers. Dry atmosphere is fatal to the nymphs.

Mechanical devices covered with sticky substances have been suggested as a control.

Aphids or Green Fly (Blattläuse, pucerons).

The aphids (Aphididae) are sucking insects, exceedingly numerous in species and individuals, but rather limited as regards any one species in their range of host plants. They are world-wide in distribution.

There are several kinds which damage legumes, e.g. *Aphis medicaginis*, the black fly of lucerne, a cosmopolitan species; *Megoura viciae*, which attacks *Vicia* and *Lathyrus* in Europe and Asia; and *Macrosiphum* (*Acyrtosiphon*, *Illinoia*) *pisi*, the pea aphid, another cosmopolitan species.

Records of aphids as pests of legumes grown for seed include the following:—*M. pisi* on field pea in the U.S.A.; aphids, probably the same species, on red clover in Idaho; aphids on *Vicia sativa* and *V. villosa* in the U.S.A. (here the pest is left to the mercy of its natural enemies); greenfly, possibly *M. pisi*, occasionally on Dorset Marl clover and on wild white clover in England (in the latter case nicotine dust was found to be effective, but too expensive); *M. pisi* (= *Acyrtosiphon onobrychidis*) on lucerne in Hungary; and aphids on *Trigonella foenum-graecum* and on cowpeas (*Vigna unguiculata* = *catjang*) in India.

The symptoms of aphid attack are a yellowing and malformation of the leaves, flowers stalks and pods. The injured leaves fall off and sometimes even the plants die. In America *M. pisi* is suspected of being the vector of a virus affecting both clover and lucerne. It also transmits the virus causing pea mosaic. The general appearance of aphids is well known and hardly needs a description. Their method of feeding is to suck the plant juice.

M. pisi passes the winter in the egg stage on the leaves and stalks of perennial legumes. There are many generations throughout the summer. Some of the aphids migrate to garden and field peas in May and June where they remain until August and September; others continue breeding on clovers, etc. Winged females appear from time to time and so migration can take place, notably in the spring from clovers to pea and *vice versa* in the autumn. Overcrowding also induces the production of winged forms and so migration. This species in England produces from 4 to 13 young daily on blossoming peas and from 3 to 10 on clover, in the U.S.A. 6 to 7 a day is the usual rate of reproduction. In this latter country it has been stated that there are 7 to 20 generations a year. One can easily imagine the enormous increase that takes place. Natural insect predators and parasites and occasionally an entomogenous fungus, however, play an important part in keeping the numbers in check; usually by mid-summer they have gained the upper hand. Unfortunately outbreaks of the aphid cannot be foretold. The host plants of *M. pisi* include among the legumes, peas, *Lathyrus*, clovers, broad bean, lucerne, vetches and cultivated broom. It has also been recorded from *Genista tinctoria* and shepherd's purse (*Capsella bursa-pastoris*). It occurs in Europe, America, Africa, India and Japan.

Control by nicotine dust has been used effectively, but is rather expensive. The dust should contain 2.4 per cent nicotine or 6 per cent nicotine sulphate and be used at the rate of 30 lb. per acre. A better result is obtained if a sheet of canvas about 20 feet long is trailed after the dusting machine, so as to confine the fumes for a few seconds. In America an aphid-collecting machine, the aphidozer, has been designed, but has not yet reached the stage when it can be recommended for use on a field scale. Harvesting a clover or forage crop as soon as it is seen to be attacked will usually reduce damage to later crops. The weather sometimes helps in controlling the population of aphids. Warm wet weather is favourable, but heavy rains wash large numbers off the plants, while cold weather and dry winds retard their development.

Plant Bugs.

The tarnished plant bug, *Lygus pratensis*, belongs to the family of sucking insects, Capsidae. It is world-wide in distribution and attacks a large number of plants including clovers and alfalfa (also beet, bean, celery, potato, cabbage, cotton, cucumber, fruit trees and many grasses and weeds). There are a number of different kinds of injurious plant bugs.

They have been specifically noted as injurious to legumes grown for seed as follows: *Lygus* on lucerne in Arizona and Utah; and *L. campestris* on lucerne in Hungary.

The leaves of attacked plants are discoloured owing to the puncture feeding marks. The flowers and buds are also malformed and pitted. The adult bugs are brownish and flattened, about 0.25 inches in length and oval in shape, with long antennae or feelers. The nymphs resemble the adults, but are not winged.

The winter is passed as adults under leaves, stones, etc. The eggs are laid in the spring, inserted in the plant tissues. In just over a week the nymphs hatch. They

moult several times and the life cycle is completed in three to four weeks. Probably three to five generations occur during the course of the summer.

No effective control is known. The destruction of favourable hibernation quarters by clearing weeds and generally clean cultivation has been suggested as a palliative. Control for fruit tree plant bugs is a different matter.

Leaf-hoppers.

Leaf-hoppers are sucking insects of the family Jassidae (Cicadellidae), of which many different kinds are known to be pests of a variety of crops. They are world-wide in distribution. Several species are injurious to clovers, alfalfa and other legumes.

Among the records of this group of insects as pests of seed production are the following: species of the genus *Empoasca* damaging lucerne in Wisconsin and Michigan in U.S.A.; leaf-hoppers on variegated alfalfa in Canada; on Swedish clover (*T. hybridum*) in U.S.A. and on *Trigonella foenum-graecum* in India.

Plants attacked by these insects become mottled and whitened in appearance due to the puncturing of the tissues, the tips wither and die owing to the loss of sap sucked out by the hoppers. The latter also puncture the plants when egg laying. Leaf-hoppers are long, slender, almost wedge-shaped insects, about 0.125 inch in length, speckled green, yellow or brownish. The young or nymphs are similar to the adults, but are more green in colour, do not hop so actively and are wingless.

The clover and lucerne leaf-hoppers pass the winter as adults. *Agallia sanguinolenta* is perhaps the best known species. The eggs are laid in the stems, buds or leaves. The nymphs moult several times before reaching the adult or winged condition. They never spin cocoons or form pupae.

As for control, cutting the first crop destroys their chances of breeding successfully. Good cultural practices, such as clean cultivation and burning the rubbish in the autumn, also reduce their numbers. Modified hopperdozers (see page 8), in which the shields are covered with sticky substances, such as tanglefoot, can also be used in times of severe outbreaks.

Pierid Butterflies.

There are several kinds of *Colias* butterflies (Pieridae) whose caterpillars are well-known pests of lucerne, e.g. the lucerne caterpillar, *C. electra* (= *electo*), in S. Africa; the alfalfa caterpillar, *C. eurytheme*, in the United States of America and Canada; the lucerne butterfly, *C. lesbia*, in the Argentine; and *C. croceus* (= *edusa*) in France. Of these *C. eurytheme* and *C. croceus* are migrant species and possibly also *C. lesbia*.

All these caterpillars eat the leaves of the plants and can strip a field. They are mainly green in colour; the butterflies are sulphur yellow with dark margins and a few dark spots with a wing expanse of about two inches. Their life cycles and control are similar. *C. electra* has been reported as occasionally damaging lucerne grown for seed in S. Africa.

C. eurytheme is probably the best known of this group. It is particularly notorious as a pest in the south-western states of U.S.A., where it sometimes has as many as five to seven generations a year; further north it has two. The winter is passed in the pupal stage on the stalks of the plants. No cocoon is spun, the pupa being attached by a loop of silken thread round its middle and by a pad of silk at the tail end. In the spring the butterflies emerge and can be seen hovering over the alfalfa plants on which they lay their eggs. These hatch in a few days and the caterpillars become full-grown in about a fortnight. In the summer the pupal stage lasts about a week. These periods vary in the different generations, the minimum total being about 26 days in the 3rd generation of the year and 64 in the first.

Control is best obtained by cutting the crop early and as low as possible. This cutting should be done immediately after swarms of butterflies have been seen in the fields and before the caterpillars have had a chance to do much feeding. After cutting, it is wise if possible to irrigate or even flood the fields as this will induce wilt disease of the caterpillars to develop. This disease on occasion has kept down the numbers considerably. Clean cultivation will assist in preventing successful hibernation of the pupae in hedgerows. Turkeys and chickens allowed free range will eat the caterpillars.

Clover Root Borer.

The clover root borer, *Hylastinus obscurus*, belongs to the family of beetles called the Scolytidae or bark beetles. It is well known as a pest of red, alsike and mammoth clovers (it is also recorded from sweet clover, alfalfa and peas) in the United States of America and Canada. It is generally claimed that it was introduced from Europe. In this latter continent it has not often been recorded as a pest.

It has been noted as a pest of red clover grown for seed in the U.S.A., and is, in fact, one of the chief factors deciding the length of utility of red clover stands after the first crop year.

Plants attacked turn brown, wilt and die owing to the tunnelling of the grubs in the roots. The grubs are small and white, about 0.1 inch long, with brown heads. The adult beetles are dull black or reddish brown, cylindrical, about one-twelfth to one-tenth of an inch long.

The beetles overwinter in the burrows on the roots. In the spring the beetles feed on the roots and in May and June lay their eggs in cavities on the crowns of the plants, on the sides of the roots and in the burrows. The grubs burrow about in the roots, becoming full grown in the late summer, and turn into pupae towards autumn. There is only one generation a year.

Control is gained by ploughing in badly attacked clover and substituting a non-leguminous crop. Only long-established clover is liable to severe damage.

Sitones or Nodule Weevils (Clover Root Curculios in the U.S.A.).

There are several species of nodule weevils, e.g. *Sitona lineata*, *S. hispidula*, *S. flavescens*, *S. humeralis*, *S. sulcifrons*, *S. crinitus*, *S. puncticollis* and *S. griseus*, belonging to the family of beetles known as Curculionidae. They occur throughout Europe, in Russia, the United States of America and southern Canada and are restricted to leguminous plants.

Among the records of damage to seed crops are the following: to seedlings of *Lupinus albus*, *L. angustifolius* and *L. luteus* by *S. griseus* in Germany; to lucerne, *Onobrychis viciaefolia* and red clover in Hungary by *Sitona* sp.; and to *Trifolium hybridum* and *T. repens* in the U.S.A. by *Sitona* sp.

The adult beetles eat U-shaped notches in the leaves, but more serious damage is caused by the grubs which attack the root nodules and hollow them out. The grubs are white and footless, about one-sixth of an inch long, with brown heads. The adult weevils are ochreous in appearance, being almost black with fuscous scales, and typically weevil-shaped.

The adults hibernate in long grass, stubble, etc., and reappear on warm days in the early spring. The eggs are then laid near the roots of the plants. The grub stage lasts one to two months and the fresh weevils emerge nearly three weeks later, i.e. late June, July and August. It is claimed in America that the young grubs of a second generation hibernate, but in Europe there is only a single generation a year.

Some sort of control is obtained by rotation and by spring ploughing. In Central Europe various beetle-catching machines are used to collect or sweep up the adult beetles. Spraying with nicotine or arsenic and the driving of flocks of turkeys through the fields are among other methods employed.

Root Weevil (*Otiorrhynchus ligustici*).

This insect is a weevil belonging to the family Curculionidae and is polyphagous, attacking many kinds of ornamental plants, fruit trees and leguminous plants, especially lucerne. It occurs throughout Europe, in Russia and in Asia Minor. There are several closely allied species which are well-known pests.

Among the records of damage by *O. ligustici* to leguminous crops grown for seed are the following: hybrid lucerne and lucerne in the U.S.S.R. and many records of lucerne suffering in Hungary.

The damage is caused by the grubs eating the roots. The adult beetle is slightly under half an inch in length and is dirty dull grey in appearance, although actually it is black with grey scales and hairs. The grubs resemble those of other weevils.

The adult beetles appear in the spring and lay their eggs in the soil. The grubs feed on the roots throughout the year; pupation takes place from the autumn onwards and shortly afterwards the weevils emerge, but remain in the pupal cells in the soil until the spring. The adults are night feeders on the leaves of the plants.

Nicotine sprays and the use of beetle-catching machines have been recommended, but as the beetles are nocturnal feeders and hide in the soil by day, such measures can hardly be of real use. A good soil fumigant is what is required. Arsenical sprays, i.e. stomach poisons rather than contact ones, should be used.

Hypera (Phytonomus) or Leaf Weevils.

There are three kinds of *Hypera* (*Phytonomus*) weevils (Curculionidae) which are well-known pests of lucerne and clovers in Europe and the United States of America, namely, *Hypera punctata*, (the clover leaf weevil in U.S.A.), *H. variabilis* (= *H. posticus*, the alfalfa weevil in U.S.A.) and *H. nigrirostris* (the clover bud weevil in U.S.A.).

The alfalfa weevil has been recorded as damaging alfalfa grown for seed in Utah.

The adults of all three species eat notches and holes in the leaves: *H. punctata* grubs attack the stems and leaves; *H. variabilis* grubs shred the tips of the new growth; those of *H. nigrirostris* chiefly feed on the buds on the stems. The grubs are green or whitish-brown, with ridges, taking the place of legs, on the underside of the body, and are from a third to half an inch long. They are usually curved. The adult weevils or beetles have quite short snouts and are greyish-brown in colour.

The eggs of *H. punctata* are laid towards the end of summer and the beginning of autumn on various parts of the plants. The grubs hatch in the autumn and feed on the young leaves. Most of the damage is done in the early spring. They become full grown in April, May and June; pupation takes place in cocoons around the base of the plants, and the adults appear in July. There is only one complete generation a year.

H. variabilis and *H. nigrirostris*, on the other hand, hibernate as adults and lay eggs in the spring. Their grubs are most abundant in June and July. They spin their cocoons among the foliage of the plants as well as on the ground around them. There is only one generation a year of both these species.

Natural control by a fungus and a hymenopterous parasite sometimes occurs in U.S.A., but spraying with lead arsenate is sometimes necessary. Two pounds of powdered lead arsenate to 50 gallons of water with one pound of soap is used at the rate of 100 gallons per acre.

Listroderes praemorsa (Subterranean Clover Weevil).

This is another weevil which, although known as a minor pest of garden crops in Western Australia for some time, was first reported as a serious pest of subterranean clover there in 1928. It also is a pest of drooping-flowered clover (*T. cernuum*) in Western Australia. This species is known at present only from Australia but has probably been introduced from South America.

The adults live for several months, appearing in September, October and November. When the autumn rains start, the weevils come out of aestivation and oviposit among the young clover seedlings. There is only one generation a year. The young grubs feed on the leaves and stems mainly at night and on dull days. Sometimes the clover is eaten to the ground. After about 12 to 14 weeks the grubs become full grown and pupate in the soil. This takes place from the end of August to the end of September and the pupal stage lasts about three weeks.

Rotation is suggested as a control. Clean cultivation prevents the successful aestivation of the adult beetles. A poison bait of 30 lb. bran, 4 lb. molasses, 1 lb. sodium arsenate with sufficient water to make a crumbling mash has proved effective in catching the grubs. Only clean machine-dressed seed should be used, as the eggs are sometimes laid in the clover heads before harvest.

Subcoccinella vigintiquatuorpunctata.

This is one of the phytophagous ladybird beetles belonging to the family Coccinellidae. It is not generally realized that in addition to the greenfly-eating ladybirds there are forms which are entirely leaf-eating.

This particular species is well known as a pest of lucerne and occurs throughout Europe. Records with direct bearing on seed production include many reports of damage to lucerne in Hungary.

The damage is caused by the adult beetles and grubs eating the leaves; that done by the adults is small in comparison with that done by the grubs. The method of feeding by the latter is peculiar. They bite the epidermal layer and parenchymatous tissue without reaching the epidermis of the opposite surface. Instead of actually eating the tissues which they have torn off, they suck them and leave the remains or fibrous matter sticking to the leaves in a long line. Having made one such line they move up the leaf and start again, and continue the process until after some hours there are a dozen such parallel lines of white tissue remains. The adult ladybird beetle is reddish with 24 black spots. The grubs are yellowish white and characterized by dorsal branched and spined finger-like processes, about six to a segment.

The adult beetles hibernate and in April start feeding on the leaves. The eggs are laid in batches of about 50 on the surface of the leaves. They are yellow and are placed with their long axes vertical to the surface. After a few days the grubs hatch and after several moults attain full growth. This takes about a month. They then pupate without a cocoon on the host plant, being attached posteriorly. In a few days the adult beetles emerge. It is not known whether there are two or more generations a year.

Arsenical sprays have been suggested as a control. Various beetle-trapping machines or implements are used in Hungary to sweep up the adults.

Mexican Bean Beetle (Bean Ladybird).

This beetle, *Epilachna corrupta*, is another leaf-feeding Coccinellid. They are reddish bronze or yellow coppery in colour, have eight black spots and are about

0.25 inch in length. This species has recently spread, probably by being carted in hay, into many parts of U.S.A. and even into Canada.

The grubs and adults devour, chiefly from the underside, the leaves of garden beans, cowpeas, soybeans and occasionally alfalfa, clovers and vetches. The grubs are stated to leave parallel lines of untouched leaf on the attacked leaves (see under *Subcoccinella vigintiquatuorpunktata*). The adult beetles hibernate and there are several generations a year. On the whole, this species is similar to the last-mentioned in regard to general habits, egg-laying and character of the grubs.

Magnesium arsenate spray or dusting with calcium arsenate mixtures or sodium fluorsilicate, if applied so as to cover the undersides of the leaves every 10 days from the time when the beetles and eggs become numerous, will protect the crop.

Phytodecta fornicata.

This is a beetle belonging to the family Chrysomelidae. There are several closely allied species, but *P. fornicata* is the most important of those attacking legumes. It is recorded as attacking lucerne in Europe, North Africa and Asia. It appears to be confined to *Medicago* species.

It is frequently mentioned by lucerne seed growers in Hungary, where it is apparently rapidly becoming one of the chief pests.

The damage is done by the larvae or grubs which feed on the leaves, petioles and stems, and to a less extent by the adults.

The beetles appear in April, and the eggs hatch in 4 to 10 days. The grubs feed for just over a fortnight and then enter the soil. After a prepupal period of about a week and a pupal one of 10 days the adult beetles emerge. They feed for two or three weeks and then enter the soil in late July and August. Here they remain in hibernation until the following spring. There is only one generation a year.

Flooding has been suggested as a control in Bulgaria, as well as the use of 2 to 2.5 lb. of Paris green and 8 to 10 lb. of lime to 100 gallons of water after the removal of the hay. In Hungary various beetle-catching implements are used, as well as lead arsenate sprays and turkeys to eat the beetles.

LEGUMES. 3. PARTICULAR AND DIRECT PESTS.

Pea and Bean Beetles or Weevils (Samenkäfer, les bruches).

These weevils attack the seeds of many leguminous plants; they belong to the family of beetles known as Bruchidae. There are many different kinds. For example: *Bruchus pisi*, the pea weevil; *B. rufimanus*, the broad bean weevil; *Acanthoscelides obsoletus* (= *obtectus*), the common bean weevil; *Pseudopachymerus quadrimaculatus*, the four-spotted bean weevil; and *Callosobruchus chinensis*, the cowpea weevil.

The distribution of these weevils is very wide, chiefly owing to the ease with which they are carried from one country to another in the seed. For example, it has been stated that of the three kinds which occur regularly in England, *B. rufimanus* is probably the only indigenous species. *B. affinis*, the Spanish bean beetle, is annually introduced from the Mediterranean region and *B. pisi* is introduced with imported peas, but it is doubtful whether it can maintain itself in the British Isles owing to the climate. The possible geographical range of insect pests is one of the problems which are at present exercising the attention of research entomologists. Pests are continually being introduced accidentally from one area to another, but fortunately some of them cannot establish themselves under the new conditions. On the other hand, some are able to do so and become greater pests under the new set of conditions than in the place of their origin.

All these weevils are of direct importance to seed producers all over the world. More often than not, however, they are considered as pests of stored seeds and not of the growing plants.

Their life cycles are similar. The adult weevils usually hibernate in the seed and if the latter are not treated the weevils may be planted with the seed. The weevils appear in the spring and feed on the foliage. The pea weevil is about one-fifth of an inch long, the bean weevils are slightly smaller, about one-eighth of an inch. The eggs are laid in holes made by the females in the green pods. The grubs are white and eat their way into a developing seed. Pupation takes place inside the seeds in a sealed chamber. In the United States of America there are several generations of the bean weevils a year in the field. Bean weevils can breed continuously in stored beans. The pea weevil on the other hand has only one generation a year; breeding does not go on continuously in stored seed and therefore no increase occurs in storage. Furthermore, only one weevil develops in a pea whereas several weevils develop in individual beans.

Control in stored seed can be easily obtained by fumigation with carbon bisulphide or sodium cyanide; 3 lb. carbon bisulphide per 1,000 cubic feet at 58°F. for 24 hours or 3 to 4 lb. sodium cyanide at 70°F. for 48 hours. Care must be taken owing to the poisonous nature of the fumigants. The use of untreated seed is asking for trouble.

Clover Seed Weevils (Spitzmäuschen, les Apion).

These are small black weevils belonging to the genus *Apion* of the family Curculionidae. There are many different kinds, at least five species being pests of legumes, particularly clovers and lucerne. These are *A. apricans*, *A. assimile*, *A. aestivum* (= *trifolii*), *A. pisi*, *A. tenue* and *A. virens*. These forms, of which the first three are the really serious pests, seem to be restricted to Europe and the U.S.S.R., although members of the genus *Apion* occur throughout the world. The species are very difficult to distinguish.

Among the records of damage to legumes grown for seed are the following : to lucerne by *Apion* sp. in Hungary ; to hybrid lucerne by *A. apricans* in the U.S.S.R.; to *Onobrychis viciaefolia* by *Apion* sp. in Hungary ; to *Trifolium incarnatum* by *Apion* sp. in Hungary ; to *T. pratense* by *A. apricans* and *A. aestivum* in England and Wales, by *A. aestivum*, the ' arch-enemy ' of the red clover seed grower in Hungary, by *A. apricans* and other species in Sweden, by *A. aestivum* in Latvia; to *T. repens* by *Apion* spp. ; and to *Vicia sativa* by *Apion* sp. in Hungary.

All these weevils feed to some extent on the foliage, but much the most serious damage is caused by their grubs, which infest the flower heads and feed on the flowers and developing seed and sometimes in the stems. The adult beetles are only about one-tenth of an inch long and have a long rostrum or beak. The grubs are minute and whitish yellow.

The exact life cycle of these species is not very well known. In the case of *A. apricans* and *A. aestivum*, the adult weevils hibernate. They come out of their winter quarters in April, but do not mate until May. They lay their eggs in holes made by their beaks in the green flower heads, one egg at the base of each flower. In 4 to 8 days the grubs hatch and, after devouring the developing ovule of one flower, pass on to the next. The grub stage lasts about 20 days and in this period they destroy from 8 to 10 flowers. Pupation usually takes place in the flower heads and the emergence of the adults follows eight days later. There are two generations a year in the case of *A. apricans* in Wales. Other workers in Europe state that there is only one.

Control is difficult. It is sometimes suggested that the first cut of clover be used for green fodder, so that the beetles may be prevented from having time to reach maturity which it is claimed they have if the first cut is used as hay. Other advice given insists that the destruction of the grubs by desiccation is considerable ; therefore if the crop is cut at the correct but early date, i.e. at 25 per cent full flower stage when the grub population is high, the maximum mortality is obtained. This advice to cut early is probably the better of the two.

If the weevils appear after the first cut, spraying with a solution of 100 litres of water with 300 grm. nicotine and 1.5 kg. potassium soft soap is recommended in Hungary. This is supported by the use of beetle-catching machines. Finnish and Danish workers have found that dusting with fluorine compounds is effective in controlling the beetles.

Clover Seed Chalcid.

This insect, *Bruchophagus gibbus* (= *funnebris*) belongs to the Eurytomidae of the super-family Chalcidoidea (order Hymenoptera). Most insects in this super-family are parasitic on other insects, but *B. gibbus*, like *Harmolita* sp., the timothy joint worm, is phytophagous.

It is generally distributed over the United States of America, Canada, Europe, the U.S.S.R. and its range extends as far as Turkey, Turkestan and Siberia. Under the name *B. funnebris* it is one of the most serious seed pests of alfalfa and clover in the U.S.A. Among definite records from seed producers are the following : to alfalfa in Nebraska, Idaho and Utah, U.S.A. and in France ; to red clover in U.S.A. and France.

The grubs of this insect eat the seeds. The adult is about one-fifteenth of an inch long, black in colour and wasp-like in appearance. The grubs are whitish yellow.

The winter is passed by the fully-grown grubs inside the infested seeds. Emergence of the adults takes place in the latter part of May and in June. The females lay their eggs inside young developing seeds. The growth of the grubs is completed

in about a fortnight to a month, and the adults appear about a fortnight later, the periods depending largely on the weather. At least one other generation is completed in the year and in some parts of U.S.A. there are three generations in the year.

Early cutting of the crop is practised as a control in U.S.A. but much dependence is laid on the insect's natural enemies. Clean seed must be used to avoid introducing this pest. Rotation of crops is suggested in France.

Clover-head Caterpillar.

This caterpillar develops into the moth *Laspeyresia interstinctana* of the family Olethreutidae. This insect is a seed pest of clovers in the eastern part of the United States of America and southern Canada.

The caterpillars feed on the young seed at the base of the florets, preventing the latter from opening. Attacked heads flower irregularly as in cases of attack by the clover seed midge (below). Usually red clover suffers, but this insect has been found on white, alsike and mammoth clovers. The moths are about 0.25 inch in size, and dark brown with six or seven short silvery-white dashes on the outer margins of the wings. Similarly coloured marks on the inner margins form a double crescent when the wings are folded. The full-grown caterpillars are greenish white in colour and about 0.25 inch long.

The winter is passed both in the caterpillar and pupal stages among stubble, etc., in clover fields. The overwintering caterpillars pupate in the spring. The moths appear just about the time that red clover is coming into flower. The eggs are laid on the leaves, stems and heads of the plants, and the caterpillars feed in the green clover heads, eating the developing seeds and moving from one seed to another. Occasionally they also eat the leaves. After about 4 to 5 weeks they spin cocoons in the clover heads and also around the base of the plants. Pupation lasts for two to three weeks. There are two or three generations a year according to the latitude.

Cutting the crop just before flowering time and removing the hay is practically the only control known. Rotation also keeps the numbers down.

The Clover Seed Midge.

This midge, *Dasyneura leguminicola*, is one of the gall midges or Cecidomyiidae. It is a serious pest of red clover seed production in the United States of America, Canada and the British Isles, and has also been reported from Norway. There are records of another species, *Dasyneura flosculorum*, doing similar damage from many parts of the European continent. It is highly probable that there is only one species of midge involved and that *D. flosculorum* should be a synonym of *D. leguminicola*.

Usually there are few signs of attack beyond irregular flowering and paucity of seeds. Attacked heads are more firm to the touch than healthy ones. Red clover is the plant which suffers most, but white, mammoth and alsike clovers have also been reported as having been attacked. The grubs are salmon pink in colour and the adult midges are small gnat-like flies.

The midges appear at about the normal period of blooming of red clover. They lay their eggs in the green head stage of the clover, up to fifty eggs being laid in one flower head. The grubs on hatching live between the ovary and the surrounding floret, feeding on the developing seed. They do not pass from one seed to another. After between 28 and 40 days they are full grown, when they wriggle out of the flower heads and fall to the ground where they pupate. This movement takes place after a shower of rain. In times of drought they remain in the heads. Pupation lasts about a week or fortnight. There are two generations a year in England and two or three in New York State. The midges are on the wing again about August. The grubs of this second generation spend the winter as full-grown larvae in cocoons in the soil.

Early cutting of the clover, which should take place about a week after the crest of emergence of the first flight of midges, is the best means of control. It is not safe to leave the first crop standing so long as there is no rain, as has been suggested, since many of the grubs will fall out of the heads as soon as cutting takes place. The second or seed crop should then be free from attack.

Contarinia medicaginis.

This is another kind of gall midge. The species of this family are usually restricted to one genus of plants. This particular species is a serious pest of lucerne in Hungary. It occurs all over Europe and its range extends into Russia.

The grubs live gregariously in the flowers and prevent the formation of seed. They are glossy yellow in colour. The adult midge is dirty yellow and of typical midge appearance, small, long-legged and delicate.

The winter is passed as full-grown grubs in the soil. The midges emerge in May and oviposit in the flower buds. The attacked flowers remain shut and swollen. It is not definitely known how many generations there are per annum. As soon as the grubs are fully fed they jump to the soil where they pupate, although some authorities claim that pupation occurs in the flower buds. This stage lasts about 8 days. Those grubs which reach the soil in the autumn do not pupate until the following spring, about 8 days before the emergence of the adult midges.

Control is very difficult. Cutting the crop and using it as green fodder has been suggested (cf. control measure for the clover seed midge).

Jaapiella (Dasyneura) medicaginis.

This is another gall midge whose larvae or grubs attack lucerne. It can hardly be considered a seed pest as the larvae live in folded leaflets. However Hungarian seed producers complain about it. Little is known regarding its exact life cycle. The species is on record from Germany, France, Italy and England. There are probably several generations a year. Pupation takes place in the soil. No control measures have been suggested.

Contarinia onobrychidis.

This is another gall midge whose grubs attack the flowers of sainfoin (*Onobrychis sativa*). It occurs all over Europe and has been noted as a pest of seed production in various parts of England.

The grubs spend the winter in the soil. Pupation takes place in the spring and the adult midges emerge in June. They lay their eggs in the flower buds, which remain shut and swollen. No seed is formed in such flowers. On reaching maturity the grubs jump to the soil. There may be two generations a year. The grubs are citron yellow, and several live in one flower bud.

Cutting the crop early and using it as fodder might prevent the second crop from being attacked (cf. control measure for the clover seed midge).

Asphondylia miki and A. websteri.

Both these insects are gall midges whose larvae cause malformation of the pods of lucerne, the former in Europe and Russia and the latter in southern U.S.A. *Asphondylia miki* is one of the pests encountered by seed producers of lucerne in Hungary.

There is little exact information available concerning their life cycles and the only control suggested is the mowing of the plants as they are coming into bloom.

LEGUMES. 4. INSECTS WHICH CAUSE DIRECT INJURY TO SEED DEVELOPMENT AND MAY BECOME PESTS.

There is only space to mention that there are several other kinds of insects known by entomologists to feed in the flowers or on the developing seeds of legumes. For example, among the gall midges, a species of *Dasyneura* on *Cajanus indicus* in India and *Contarinia loti* on trefoils in Europe.

The underlying principles governing the appearance of insects in sufficient numbers as to warrant their being considered pests are only vaguely understood. In some cases, epidemic numbers seem to occur rhythmically, in others only spasmodically. The relationships between the natural enemies and the injurious insects are being studied more and more; similarly the effect of climate and weather on pests is being investigated. In this case, although one can hardly hope to change the climate or weather, a full understanding might enable predictions to be made and so precautions to be taken.

CONCLUSIONS.

This paper is essentially a summary of the available information concerning some of the insect and other pests injurious to the production of seed in grasses and legumes. Although no references have been inserted, all the facts given have been checked in the light of the most recent research. The result is that, whereas growers and others should find a considerable amount of information concerning the pests in this bulletin, advice regarding the actual safeguarding of their crops should always be obtained by consulting entomologists in their particular areas.

The position can be briefly stated as follows. Many kinds of insects attack grasses and legumes and, indirectly or directly, do a great deal of damage. Their life histories, modes of attack and control are exceedingly varied. There are many gaps in the available knowledge which will have to be filled before control measures can be expected to be really successful. The lack of adequate control measures in so many instances is appalling.

The control measures mentioned indicate two main lines of approach, namely, by means of the application of chemicals and by the slight alteration of cultural practices. The former, with such other methods as trapping, are of necessity only palliative or curative, i.e. they are used when the insects are already present and usually by this time the damage has been done. The latter are preventive and more to be desired both on account of their relative cheapness and their more lasting effect. It is in the actual designing of such methods that the intimate co-operation of the grower, agronomist and entomologist is essential and their respective knowledge should be pooled. For example, the early cutting of red clover to avoid clover seed chalcid, clover seed weevils, clover-head caterpillar and clover seed midge attacks is an underlying principle. The exact dates to obtain the best results in different areas must be fixed by the grower, agronomist and entomologist in consultation. It is no use cutting the crop, if it will not produce another crop of flower heads later in the season ; similarly if the first crop is cut too late either for the second crop to ripen or after the pests have developed sufficiently far to survive, the whole effect is lost. Likewise and perhaps most important, it is futile to advise a grower to carry out some cultural method at a time when of necessity all his attention is demanded by other urgent affairs on the farm.

Prevention is better than cure and at last this is being realized. As a start, growers and traders should always insist on clean seed. This is elementary but often overlooked. Next the growers should continually agitate the entomologists to find out weak and vulnerable points in the insects' lives and also the plant breeders to find resistant varieties of crops. The entomologists and plant breeders should in retaliation insist that the growers take advantage of preventive measures as they become available. The ideal to be aimed at is that the use of palliative methods should be considered an admission of bad management and as such to be avoided.

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